



DEFENSE CENTERS OF EXCELLENCE
For Psychological Health & Traumatic Brain Injury

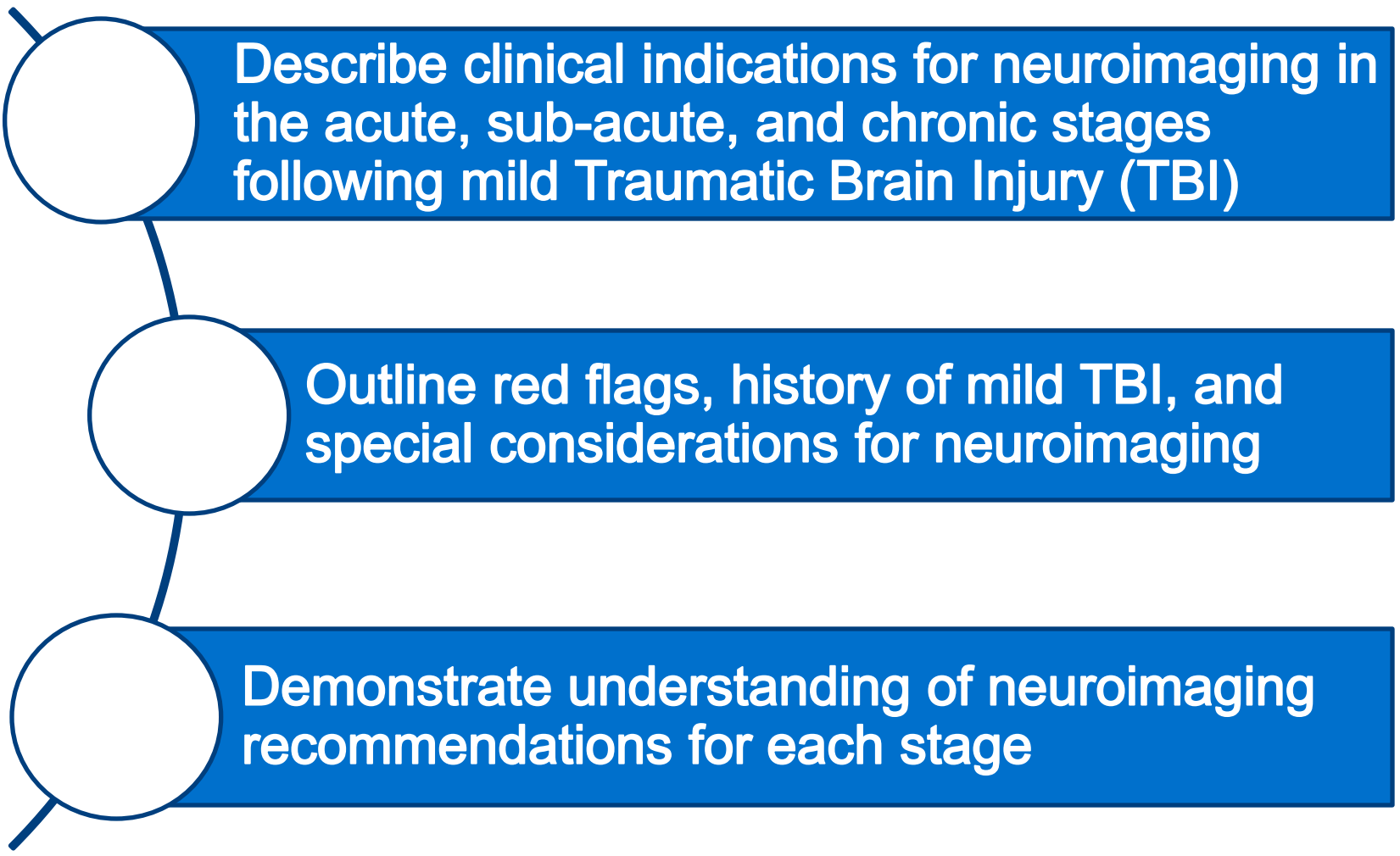
Clinical Recommendation:

Neuroimaging Following Mild Traumatic Brain Injury (Non-deployed Setting)

Provider Education



Learning Objectives



Describe clinical indications for neuroimaging in the acute, sub-acute, and chronic stages following mild Traumatic Brain Injury (TBI)

Outline red flags, history of mild TBI, and special considerations for neuroimaging

Demonstrate understanding of neuroimaging recommendations for each stage

Scope of Clinical Recommendation

The *Neuroimaging following Mild Traumatic Brain Injury (mTBI)* clinical recommendation (CR) and companion clinical support tool (CST) offers guidance for Military Health System (MHS) providers as a standard approach for imaging from the acute through chronic stages following mTBI in the non-deployed setting.

Guidance for neuroimaging following mTBI in the deployed setting is addressed by the CENTCOM Joint Theater Trauma Systems (JTTS) Clinical Practice Guideline* (CPG), the Department of Defense Instruction (DoDI) 6490.11 “Department of Defense Policy Guidance for the Management of mTBI/ Concussion in the Deployed Setting,” the VA/DoD CPG “Management of Concussion/ mTBI, and the Concussion Management Algorithms (CMAs).



DoD Photo
Source: DCoE Blog

Closed TBI Classification

Severity	Mild	Moderate	Severe
Structural imaging	Normal	Normal or abnormal	Normal or abnormal
Loss of consciousness (LOC)	0 to 30 minutes	> 30 minutes and < 24 hours	≥ 24 hours
Alteration of consciousness (AOC)	a moment up to 24 hours	> 24 hours severity based on other criteria	
Post traumatic amnesia (PTA)	24 hours	> 24 hours and < 7 days	≥ 7 days

*Source: Assistant Secretary of Defense for Health Affairs. Health Affairs Memorandum (October 1, 2007).
Traumatic Brain Injury: Definition and Reporting*

- This classification refers to severity at the time of injury, not symptoms experienced

Clinical Recommendation

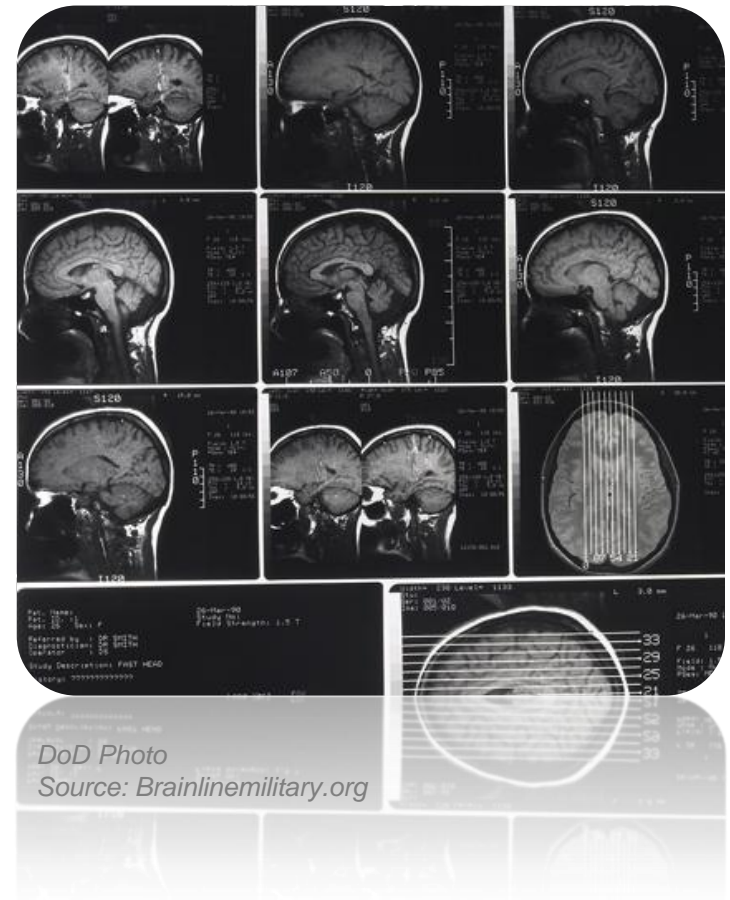
Neuroimaging is recommended for the evaluation of service members (SM) with clinical red flags*, new onset or persistent or worsening symptoms and individuals whose recovery is not progressing as anticipated.

Red Flags and Indications for Neuroimaging			
Progressive declining level of consciousness (LOC)	Progressive declining, neurological exam	Focal neurological deficit: motor or sensory, slurred speech	Cannot recognize people or disoriented to place
Pupillary asymmetry	GCS < 15	Double vision	LOC > 5 minutes
Seizures	Worsening headache	Visible physical injury above clavicle	Repeated vomiting
Drug or alcohol intoxication	Coagulopathy	Unusual behavior	Age > 60

*(CMA and New Orleans' Criteria apply for CT Scan)

Discussed Neuroimaging Techniques

- Computerized Tomography (CT)
- Magnetic Resonance Imaging (MRI)
- Positron Emission Tomography (PET)
- Single Photon Emission Computed Tomography (SPECT)



Stages of mTBI

The specific neuroimaging recommendations are discussed related to the following three timeframes post mTBI:

- Acute – time of injury to 7 days post-injury
- Sub-acute – 8 to 89 days post-injury
- Chronic – 90 days post-injury and beyond

Acute Stage

Acute: Time of injury to 7 days

- **Neuroimaging is not routinely recommended for evaluation following mTBI**
- Goal: Identify risk for surgical mass or lesions via **clinical red flags**
- Key Point: Less than 1% of mTBI patients require surgical intervention ⁷

Computed Tomography (CT) scan is the recommended acute imaging modality when imaging is indicated

Computed Tomography

The most common imaging test is computerized axial tomography (CT or CAT scan) and features:

- Use of ionizing radiation (x-rays)
- Produces thin, overlapping slices which allow reformations into multiple planes (multi slice >16) with slice thickness no greater than 5mm
- Allows anatomic localization of injury
 - Detection of size and location of hemorrhage
- May help determine therapeutic intervention
 - Surgical vs. non-surgical
- Can help determine the anatomic area of damage

Computed Tomography

Advantages

- Fast, inexpensive, high linear resolution
- Helpful for evaluation of fractures (skull base, C-spine)
- Can be used in sub-acute and chronic patients if MRI is contraindicated

Disadvantages

- Ionizing radiation
- Limited functional information
- Lower sensitivity than MRI for Diffuse Axonal Injury (DAI)

MRI in Acute Stage

Indications for MRI in Acute Stage include:

- Sustained a concussion with alteration of consciousness (AOC) to include any memory loss greater than 15 minutes and has persisting or worsening symptoms after 72 hours.
- Sustained concussion with loss of consciousness (LOC) greater than 30 minutes and has persisting or worsening symptoms after 72 hours despite a normal CT.
- Sustained three or more concussions in past 12 months.
- Has a documented diagnosis of concussion and has a Military Acute Concussion Evaluation (MACE) Cognitive Score of less than 25, after 72 hours post-injury.

Sub-acute Stage

Sub-acute: 8 to 89 days after injury

- Goal : Evaluate SM, enhance understanding of symptoms, provide education, and identify the need for specialist referral
- Key Points:
 - Treatment relies heavily on trajectory of symptoms
 - History of injury is critical to making right decision

Minimum requirements for MRI are outlined in the Preferred 1.5 T Protocol (Appendix A)

- MRI should be complete before referral to specialty care
- If MRI is unavailable or contraindicated, CT is the modality of choice

Sub-acute Stage

Key Considerations

- Trajectory of symptoms
 - Is the SM seeing improvement or worsening of symptoms?
- Functional impact on the SM
 - Does SM have the ability to rest or is there a requirement to return to normal activities immediately?
- SM's history of concussions
 - Has the SM experienced more than one concussion? If so, how many and over what period of time?
- SM's history of examination and assessments
 - How many visits to medical care has the SM had since time of injury?
- Symptom tracking and documentation
 - How symptoms being documented and what is being used to track symptoms?
Example: Neurobehavioral Symptom Inventory
- SM's history of imaging after injury
 - If indicated, has cervical spine imaging been completed?

Magnetic Resonance Imaging

Features of Magnetic Resonance Imaging (MRI):

- Higher contrast resolution image
 - Can detect subtle intracranial pathology
- NO ionizing radiation (radiofrequency)
- True multi-planar imaging
- Relies on contrast of tissues to image
 - Example: water, fat molecules
- Physiologic and metabolic imaging
 - Flow (blood, cerebrospinal fluid)
 - Can perform spectroscopy



DoD Photo
Source: Brainlinemilitary.org

MRI at 1.5 Tesla has been reported to detect different markers of cerebral injury in 30% of individuals that have a normal head CT ²³

Advanced Neuroimaging

Sub-acute stage:

If there are no structural abnormalities identified on the MRI or CT, and/or abnormalities do not explain persistent symptoms, following advanced neuroimaging techniques may offer additional information in the understanding of sequelae following mTBI :

- Positron Emission Tomography (PET) or
- Single-photon Emission Computed Tomography (SPECT)

Nuclear Medicine Modalities

Positron emission tomography (PET)

- Uses metabolic function to determine cerebral blood flow
 - 2-deoxy-2-(18F)fluoro-D-glucose
- Can detect decreased or increased metabolism in frontal and parietal lobes
 - Molecular imaging of inflammatory/ excitotoxic markers using a glutamate isotope.

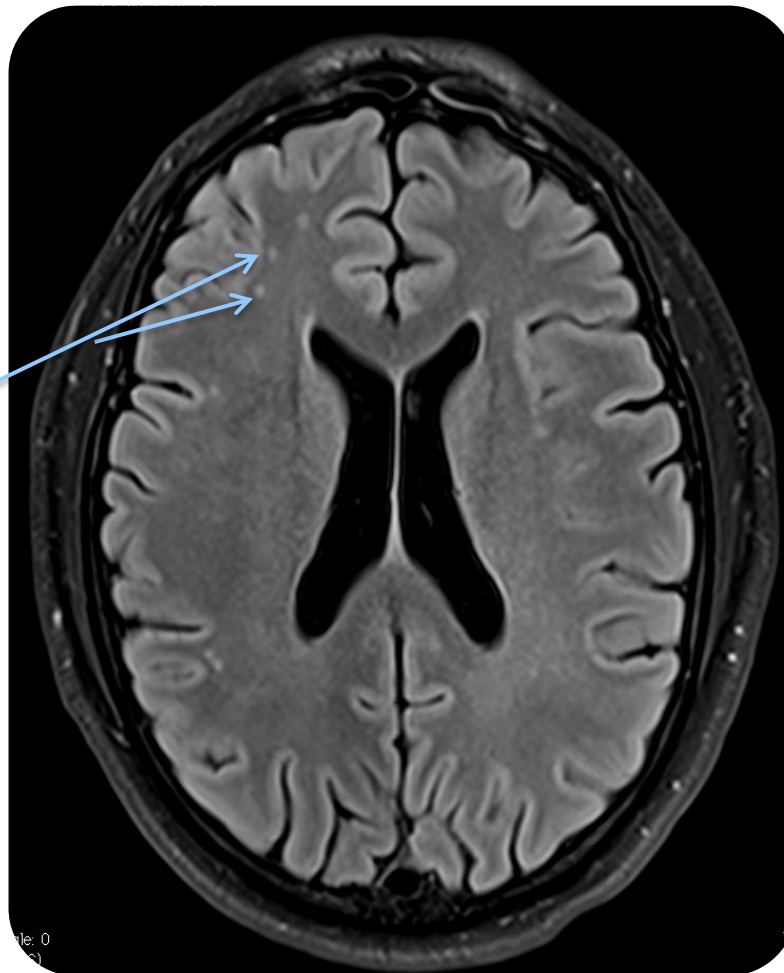
Single Photon Emission Computed Tomography (SPECT)

- Uses short-lived radio active particles to determine blood flow
 - Technetium 99m-hexamethylpropylene amine oxime (99mTc-HMPAO)

Relationship Between Neuroimaging Techniques and mTBI Pathology

Mild TBI Pathophysiology	Recommended Imaging Technique
Axonal Injury/White Matter Injury	<ul style="list-style-type: none">• Fluid Attenuated Inversion Recovery (FLAIR)• Diffusion Weighted Imaging (DWI)• 2-Dimensional/ 3-Dimensional (2D/3D) T2
Traumatic Sub-Arachnoid Hemorrhage (tSAH)	<ul style="list-style-type: none">• FLAIR• 3D T1• Susceptibility Weighted Imaging (SWI)/Gradient Echo (GRE)
Cortical Contusions	<ul style="list-style-type: none">• FLAIR• 3D T1• SWI/GRE
Vascular Injury	<ul style="list-style-type: none">• SWI/GRE
Volume Loss	<ul style="list-style-type: none">• 3D T1

MRI: Fluid Attenuated Inversion Recovery (FLAIR)

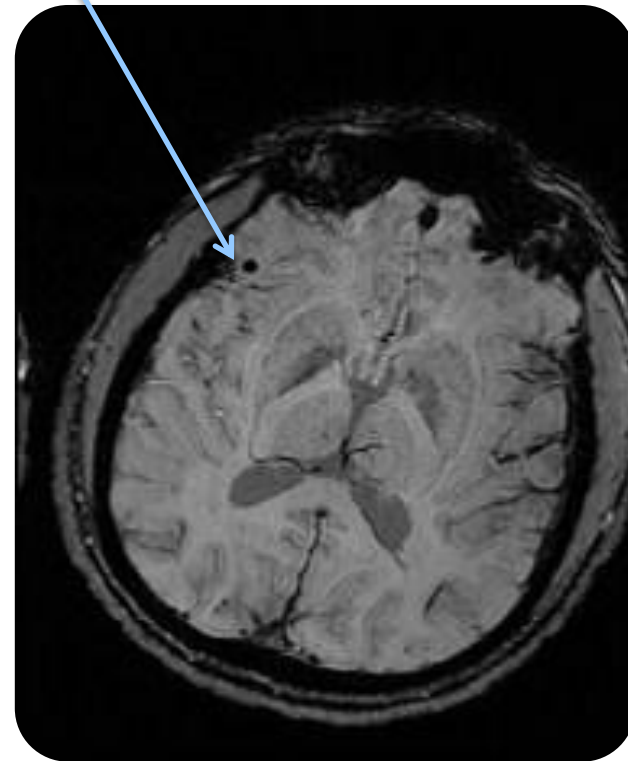
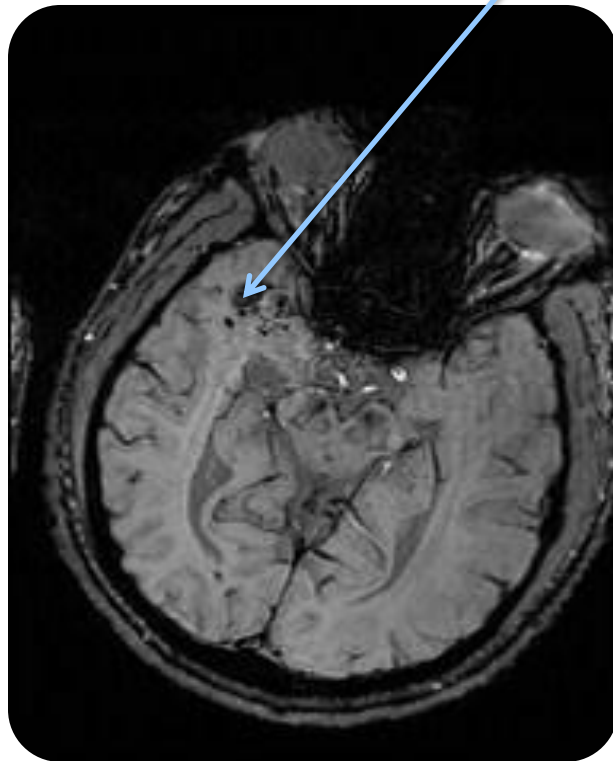


Axonal Injury / White
Matter Injury

DoD Photo
Source: LTC Gerald York

MRI: Susceptibility Weighted Imaging (SWI)

Micro hemorrhages



Chronic Stage

Chronic: 90 days after injury and beyond

- Goal: Further evaluate SM's injury, enhance understanding of persistent symptoms, provide counseling/education, identify need for specialty referral
- Key Points:
 - Repeat subsequent imaging if the previous exam was a CT
 - Repeat is also suggested if a previous MRI indicates need for follow-up, or if it did not meet the minimum recommendations sufficient for exam
 - If there are no structural abnormalities identified on the MRI or CT and/or abnormalities do not explain symptoms, PET or SPECT may offer additional information in the understanding of sequelae following mTBI.

Patient Education

The following recommendations must be considered when educating patients on the need for neuroimaging after an mTBI:

- Neuroimaging is not routinely recommended for all individuals who have sustained an mTBI
 - Patients may have expectations of imaging that cannot be met or may not change therapy
 - Unnecessary testing can be harmful

Most patients with mTBI recover fully within five to seven days and do not require additional interventions.

Special Considerations

Pregnancy

- Women of reproductive age should be screened for pregnancy
 - Documentation and risk-benefit analysis required
- Head CT exposure is <0.01 rad of ionizing radiation
 - Very low fetal risk
- No harmful fetal effects from MRI are currently known
- Contrast agents, i.e. gadolinium, should NOT be administered during pregnancy
 - Consult radiology for possible alternatives

Knowledge Check

Knowledge Check

What is true about neuroimaging following mTBI?

- a) Neuroimaging should be considered for all patients who have sustained an mTBI
- b) It is not the role of primary care provider to order neuroimaging for patients with an mTBI diagnosis
- c) MRI is the modality of choice for patient in the acute stage following an mTBI
- d) Neuroimaging is not routinely recommended for the evaluation of all SM following an mTBI

Answer: D

Knowledge Check

Which of the following signs/ symptoms are indications for a CT scan in the acute stage for a patient who sustained an mTBI?

- a) Repeated vomiting
- b) Progressively declining neurological status
- c) Brief LOC
- d) Answer A and B
- e) All of the above

Answer: D) Repeated vomiting and declining neurological status are indications for CT.

Knowledge Check

What is the primary role of neuroimaging during the sub-acute stage?

- a) Evaluate symptoms and identify the need for specialist referral
- b) Identify risk for surgical mass or lesions via clinical red flags
- c) Avoid unnecessary testing
- d) Repeat Computerized Tomography (CT) if mTBI symptoms persist.

Answer: A) the primary role of neuroimaging during the sub-acute stage is to evaluate symptoms and identify need for specialist referral

Knowledge Check

Which of the following are recommended clinical indications for conducting an MRI in the acute stage following a CT scan?

- a) If symptoms are persistent or worsening after 72 hours or clinical red flags are present
- b) History - the patient has sustained three or more concussions in the past 12 months
- c) Sustained a concussion with >15 minutes' LOC
- d) All of the above

Answer: D) all are indications for conducting MRI during acute stage following a CT scan

Case Study

Maj. James Smith, a 46 year-old male, was taken to a civilian ER following a motor vehicle accident. He was diagnosed with an mTBI/concussion, contusion to the right clavicle, and shoulder dislocation. The CT of his head was negative for a bleed/fracture. His physical exam was normal except for right shoulder dislocation, and contusion of the clavicle. He complained of a headache and dizziness, and received appropriate treatment. He was admitted for observation and subsequently discharged after all of his symptoms subsided.

He presents at the base clinic nine days post-injury for a follow-up visit with his primary care provider with symptoms of reoccurring headache and dizziness. He is also complaining of a new onset of confusion and sensitivity to light.

The provider evaluates the patient's symptoms, determines that there are no red flags present, and determines the course of treatment.

Case Study

What should be the best course of action that provider should take given Maj. Smith's symptoms?

- a) Order a repeat CT
- b) Order a MRI
- c) Refer patient to specialty care
- d) Educate that patient on symptoms of concussion, and reaffirm that neuroimaging is not necessary in his case

Answer: B) MRI is the neuroimaging modality of choice during the sub-acute stage when there are new, persistent, or worsening symptoms. MRI should be conducted prior to specialist referral.

Clinical Reference Tool

Red Flags and Acute Imaging Indications (CMA¹ and New Orleans's Criteria for CT Scan²)

Progressive declining level of consciousness (LOC)	Progressive declining neurological exam	Focal Neurological deficit: motor or sensory	Cannot recognize people or disoriented to place
Pupillary asymmetry	Clinically verified GCS < 15	Double vision	LOC > 5 minutes
Seizures, repeated vomiting	Worsening headache	Visible physical injury above clavicle	Slurred speech
Drug or Alcohol		Unusual behavior	Age > 60

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Neuroimaging Recommendations following mTBI



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No imaging is recommended if symptoms are improving

Modality	Clinical Indications in Setting of mTBI	Acute (0-7 Days) GOAL of IMAGING: Identify surgical mass or lesions via Clinical red Flags	Sub-Acute (8-89 Days) GOAL of IMAGING: Evaluate, enhance counseling, identify need for referral	Chronic 90 days or greater GOAL of IMAGING: Evaluate, enhance counseling, identify need for referral
CT	Utility varies based upon length of time between injury and presentation	Modality of choice if clinical evaluation indicates	Use only if MRI is contraindicated	Use only if MRI is contraindicated
MRI	Minimum requirements of a mTBI exam includes: 1.5 tesla or above with 3D T1/T2, FLAIR, DWI/DTI, SWI/GRE SWI/ GRE SWI may identify areas of prior DAI or prior micro hemorrhage. GRE may be substituted if SWI not available or run as a complimentary exam DWI trace maps calculated from DTI data may be substituted for conventional DWI	If symptoms are worsening after 72 hours	Modality of choice	Modality of Choice DWI has low yield for patients with chronic mTBI and persistent symptoms
PET	18 FDG-PET	No clinical indication	If no structural abnormalities identified on MRI or CT and/or abnormalities do not explain symptoms then consider PET to identify comorbid conditions that may mimic mTBI	If no structural abnormalities identified on MRI or CT and/or abnormalities do not explain symptoms then consider PET to identify comorbid conditions that may mimic mTBI
SPECT	If PET not available, consider HMPAO or ECD SPECT	No clinical indication	If no structural abnormalities identified on MRI or CT and/or abnormalities do not explain symptoms, then consider PET to identify comorbid conditions that may mimic mTBI	If no structural abnormalities identified on MRI or CT and/or abnormalities do not explain symptoms, then consider PET to identify comorbid conditions that may mimic mTBI

Neuroimaging Techniques and Physiology

Imaging Technique
Inverted Inversion Recovery (FLAIR)
Weighted Imaging (DWI)
Weighted Imaging (SWI)/Gradient Echo (GRE)

Information for the PCP to collect

Example
Is the patient seeing improvement or worsening of symptoms?
Does patient have the ability to rest or is there a requirement to return to normal activities immediately?
Has the patient experienced more than one concussion? If so, how many and over what period of time?
How many visits to medical care has the patient had since time of injury?
Use of Neurobehavioral Symptom Inventory to understand symptoms
If indicated, has C-spine imaging been completed?

Defense Centers of Excellence for Psychological Health and Traumatic Brain Injury

Defense and Veterans Brain Injury Center

1335 East West Highway | Suite 6-100 | Silver Spring, Maryland 20910

www.DVBIC.org | www.dcoe.health.mil

Outreach Center 866-966-1020



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Conclusion



The role of this clinical recommendation is to provide an evidence-based standard approach to neuroimaging following mTBI

Neuroimaging is not routinely recommended for evaluation of all SMs following mTBI

CT and MRI can be ordered by primary care providers

The possible need for more complex imaging (PET or SPECT) or nuclear imaging should involve consultation with subspecialty providers

Unnecessary imaging increases patient risk and cost without sufficient benefit

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